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AN IOT BASED UNDERGROUND CABLE FAULT DETECTION TECHNIQUE

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ABSTRACT

In this paper, a model is designed for underground cable fault location using a microcontroller and the Internet of Things (IoT). The objective is to evaluate the distance of underground cable fault from the underground cable ground station in kilometers, and also to find the correct location of the faulty spot. The currently existing methods involved with the underground fault detection employed in India are very tedious and tiresome to use. These are also very inefficient. Consequently, they lead to a waste of time and money. This method involving the Internet of Things technology saves money, time as well as efforts required in servicing all these underground cables. This allows the authorities to monitor and check faults over the internet by connecting the system to a web page and time-efficient technique catering to an ever-increasing need for modernization and digitalization.

Keywords: Underground Cables, Internet of Things, Fault Detection.

Introduction

India has more than 350 million of overhead cables across the country. On top of this, there are more than 200 million telephone and cable television lines. Natural disasters like hurricanes, earthquakes, fires, and hail or snowstorms create a nuisance and destruction on these cables and systems which create a lot of monetary loss. These utility breakdowns last for many days and sometimes even months. Power outages create serious health & safety issues over the extended periods, along with many disruptions to the economy. The concerns about the reliability of these over-headlines and the ever-increasing costs of maintenance and operations along with the issues of putting public safety at risk have influenced more organizations to convert the overhead cables to underground ones. This will ensure to bring high-quality service to their consumers as the public safety risk will be minimal and it will result in a better quality of life. For the utility companiesconverting overhead cables to underground cables provides many benefits through a reduction in operational and maintenance costs, less tree cutting expenses, reducing rainstorm damage and minimizing loss of daily electricity sales when the consumers lose power after these natural calamities (Sidhu et al., 2010).

Sidhu et al. (2010) discussed the faults of underground cables caused mainly due to holes in cable insulations or by defects in the equipment of the cable and its network, and provided algorithms that helped to identify incipient faults in underground cables based on the analysis of superimposed fault current. Shi et al. (2010) discussed the localization of the faults that occur in underground cables for communication systems, power distribution systems, and automobiles are very important. Methods of reflectometry are frequently used to identify and locate faults in cables. Naidu et al. (2017) discussed the advantages of using underground cables over overhead lines which made the use of cables wider and more applicable in electrical models. Islam et al. (2010) proposed the design for a simple, lightweight instrument that can be used to insert a pulse of very high voltage using a hot stick to a cable and for monitoring the reflected signal to find the fault distance. Pandey et al. (2012) provided a method for detection of a fault in underground cables which performed Fourier analysis of the voltage measurements. The model of cable depicted in this paper was not accurate. It did not consider sheath current and the different modes of grounding. Clegg et al. (1993) have presented an improvised algorithm for underground cables which are quite aged. The algorithm is a fault position algorithm, based on multi-terminal input. Choe et al. (2005) proposed a method for fault detection using the method of vector machine approach. The one terminal voltage's frequency characteristics and the signals of the transient current were employed in this method.

Underground cables are subjected to lots of faults due to geological temperatures, earth insects and rats, etc. The detecting of fault origin is difficult & the whole line must be dug so that it can be checked that the entire line is okay or not and to rectify the faults. So here we developed a model which enables cable fault detecting over IoT, which detects the exact fault location over IoT, making repair work very easy. The engineer and repair person will know the exact location of the fault so only that area is to be dug to identify the fault source. This saves money, time, as well as labor required in servicing all these underground faults. IoT technologies have to be used that allow the system to examine and check faults over the internet by connecting the system to a web page www.iotgecko.com so that a full digitalized system is obtained.

In this paper, an effective underground cable fault detection system is designed based on the concept of the Internet of Things (IoT). The equipment along with giving a signal on detecting a fault will also tell the correct location at which the fault occurred by employing the use of a Wi-Fi module.

Working principle

When any of the twelve switches (which represent fault switches) are operated, they give rise to conditions similar to the line to ground (LG), the line to line (LL) and line to line (3L) faults. The software scans continuously when operating using an IoT-based technique by running the three relays in a series of one-second intervals. Consequently, the voltage drop at the analog to digital converter (ADC) pin depends on the current flow which is inversely proportional to the resistance magnitude indicating the length of the cable in kilometers. To develop an 8-bit1data for the microcontroller, the varying voltage is fed to the ADC. The program shows output at the distance of the fault occurring in kilometers while executed. In a faulty situation, if the 3 km switch is made ON it displays R=3 km. According to this, other faults are also indicated (Buccella et al., 2012 and Clegg et al., 1993). This is appropriately explained with the help of the circuit diagram in Figure 1 when the fault is simulated.

2.1 Assumptions and Constraints

- Implementing this prototype on a large scale would require digging up of previously laid cables to install the setup after every few kilometers. This can be

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worrisome and may be difficult to carry forward. But such a new method can be employed on new cables and in areas which are under development.

- It has been assumed that the resistance between the cables shorted is zero, whereas in an actual application the resistance will never be zero because of the effect of nearby cables.
- One major constraint is that on the occurrence of two faults in the same cable, the fault nearer to the model will be detected first and after rectification of this fault will the second fault be detected.
- Another constraint is that, it has been considered that only faults between red and yellow will occur, yellow and green will occur, and green and neutral will occur. The circuit shown in the prototype will have to be changed to incorporate other faults.

Design Methodology

The block diagram in Figure 2 is a combination of ATMEGA 328 microcontroller along with various other components such as relays, switches, Wi-Fi modules, display and voltage regulators. The working of the prototype occurs in such a manner as to when the fault is simulated by closing one or more switches among the twelve switches present, a display indicates about the occurrence of the fault and further, the signal of occurrence of fault is sent via the Wi-Fi module to the website on the internet which displays the fault digitally.

3.1 Algorithm

Step 1: Initialize the ports and declare timer. After this, the functions of LCD and ADC are added.
Step 2: Turn on the relay number 1 by making the PIN 0.0 high in an infinite loop.
Step 3: Show the value "R:" at the beginning of the first line on the LCD.
Step 4: ADC Function is called; fault location is displayed according to the displayed ADC function.
Step 5: Call delay.
Step 6: Repeat Steps 3 to 5 for the rest of the remaining two phases (Choi et al., 2005).

3.2 Mathematical Analysis and Calculations

3.2.1 Murray Loop Test

The Murray Loop Test is specifically used to determine the underground cable's fault location by constructing a Wheatstone Bridge inside it, and then by measuring the resistance in the bridge, the location of the fault should be determined. The Murray loop test connections are shown in Figures 3 and 4 respectively. Figure 3 represents the circuit to detect the location of the ground fault while Figure 4 displays the circuit to find the short circuit fault position when occurs. (Bascom et al., 2014 and Fonseca et al., 2012).

In this test, the faulty cable has been connected to a normal and perfect cable with a wire of low resistance, so that resistance does not influence the cable's total resistance and the flow of current in the loop to the circuits of the bridge without any loss. The R1 & R2 resistors are variable and are responsible to form the ratio arms. G is the galvanometer used to show the balance and bridge balance is maintained by the adjustment of the variable resistors. (R_X+R_3) indicates the total resistance of the faulty cable and the sound cable. When balance is achieved, the conditions are as follows shown by the equations (1-3) below,

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$$\frac{R_1}{R_2} = \frac{R_3}{R_X} \quad (1)$$

$$\frac{R_1 + R_2}{R_2} = \frac{R_3 + R_X}{R_X} \quad (2)$$

$$R_X = R_2 \times \frac{R_3 + R_X}{R_1 + R_2} \quad (3)$$

If the cross-sectional areas of both the solid cable and the defective cable are equal then the conductor's resistance is directly proportional to their lengths (IEEE Standard for Microcontroller System Serial Control Bus, 1991). Therefore, if L is the cumulative length of both cables and L_X is the length between test end to the fault end of the defective cable then the equation for L_X is represented as (4),

$$L_X = L \times \frac{R_2}{R_1 + R_2} \quad (4)$$

If the cable length is known then the above test shows the effect and the fault resistance is also fixed in Murray Loop Test, and it might not be varied. Bridge balancing is very hard and therefore, the assessment of the fault location is less reliable. Due to high current and high voltage, the current that circulates through the cable would cause a rise in temperature. If the resistance changed due to the temperature change, then the balance breaks. It is, therefore, necessary to apply minimum current or voltage to this circuit (IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters, 2011).

3.3 Simulation Set-Up

An approximate circuit of the main circuit was modeled using PROTEUS software. The Simulink model is shown in Figure 5. The four sets of resistances i.e. R9, R10, R11, R12, and R13, R14, R15, R16, and R17, R18, R19, R20, and R21, R22, R23, R24 in series representing cables and twelve switches representing faults are simulated using Proteus software as shown in Figure 5. Figure 1 shows the generation of faults in the form of a circuit diagram. The simulation output is shown in Table 1 given below.

Results and discussions

4.1 Simulation Results

In this approach, the short circuit fault in the underground cable can be located at a particular distance using simple concepts of Ohm's law. The Proteus software was used to simulate the model, check feasibility and output results. The coding of the microcontroller was performed on Arduino Software and its working was tested on Proteus (Qualifying Electric Cables, 2016). The coding was carried out after dealing with the practical constraints related to real-time LDR output values. Figure 7 shows no fault in the cable as all the switches are kept open as mentioned in Table 2. IoT based simulation of underground fault detection is carried out using Proteus software and a fault is detected at 2 km of Y cable when switch 5 is closed as shown in Figure 8. Figure 9 shows fault detected at 2 km of R cable when switch 1 is open. Figure 10 shows fault detected at 2 km of R, 4 km of Y and 6 km of G cable when switch 1, 6 and 11 are kept open.

4.2 Hardware Results

The hardware setup is installed with a set of resistors representing cable length in kilometers, and a set of switches is generated at each kilometer to check the accuracy of the same. The voltage drop across the feeder resistor is provided to an ADC that produces accurate digital data which would be displayed in kilometers by the programmed microcontroller (Thermal Resistivity Measurements, 2003). The fault which occurs at what distance and which phase is shown on an interfaced 16x2 microcontroller. So far the fault positions are obtained correctly at nearby points. If there are two faults in a cable, firstly the nearby fault is detected. Figure 11 indicates the fault at 3 km of Y cable and at 1 km of G cable, and switch 7 and 9 are open in this case. Figure 12 shows no fault in the cable and all the switches are closed during this period.

4.3 Discussions/ Inferences Drawn

1) Originally, when all the switches in the model are open, there is no fault simulated in the circuit. R, Y, G on the experimental setup displays OK as their output and the iotgecko.com portal shows all the cables intact in a continuous manner.

2) When a fault is simulated in any cable by closing a switch, the R, Y, G on the experimental setup changes to show the occurrence of a fault by showing the distance at which the fault has occurred according to the resistance

Conclusions

After replacing the ongoing methods of detecting faults in underground cables with this new model implementing new and latest technologies like IoT to an underground cable fault detector will increase efficiency. It will also reduce the manpower requirement. A lot of energy will be saved and this shall help boost our economy. Huge microprocessor-based setups are required to be installed to attach such a system to the existing underground cables. Besides this IoT based underground cable fault detector is a very time efficient technique catering to an ever-increasing need for modernization and digitalization. The device can be modified to support GSM, which is Global System for Mobile Communication; and be connected via a SIM (subscriber identity module) card so that along with the fault message coming on the web page, the is also delivered as a text message. This text message will be delivered to the device having the SIM card which was connected via the code. This will make the model even more advanced and easy to use as the cable fault occurrence will be known even if the engineer is miles apart and adequate information can then be sent to the repairman immediately.

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Figure 1 Circuit diagram

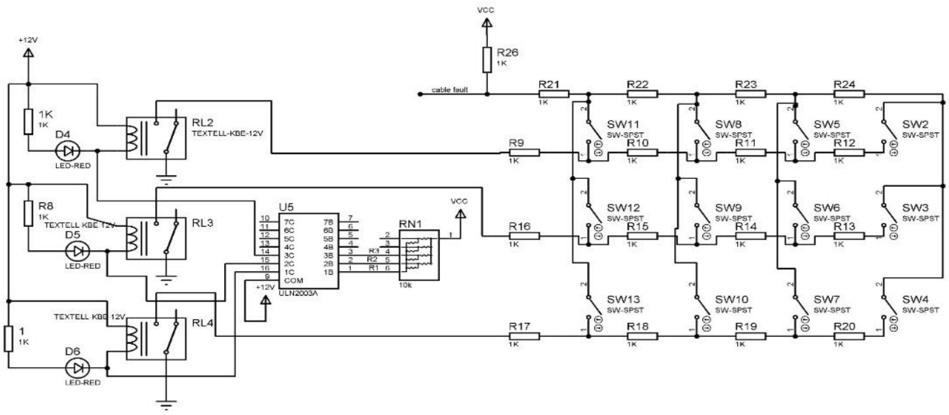

Figure 2 Block diagram of the underground cable fault detector

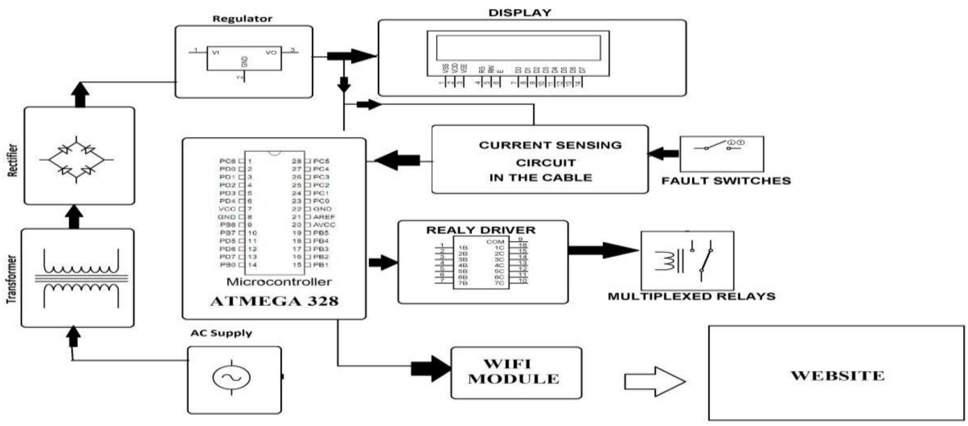

Figure 3 Murray loop test circuit for ground fault

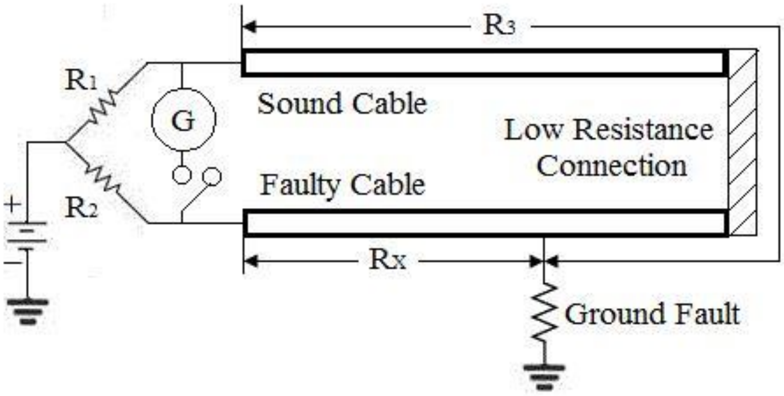

Figure 4 Murray loop test circuit for short circuit fault

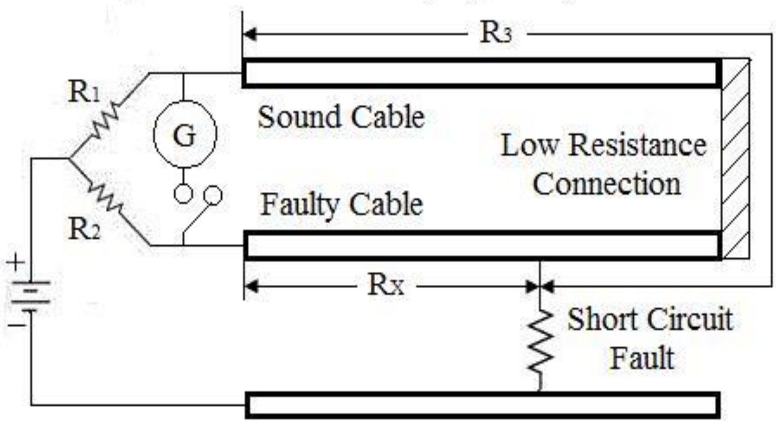

Figure 5 Proteus setup

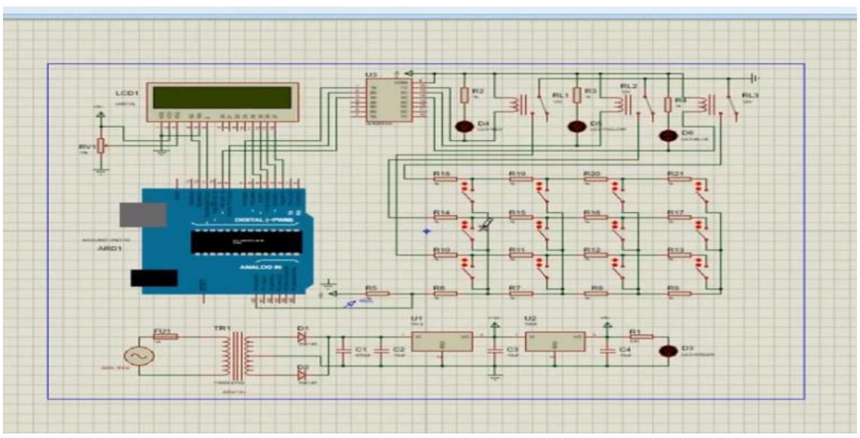

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Figure 6 Simulation of IoT based underground fault detection

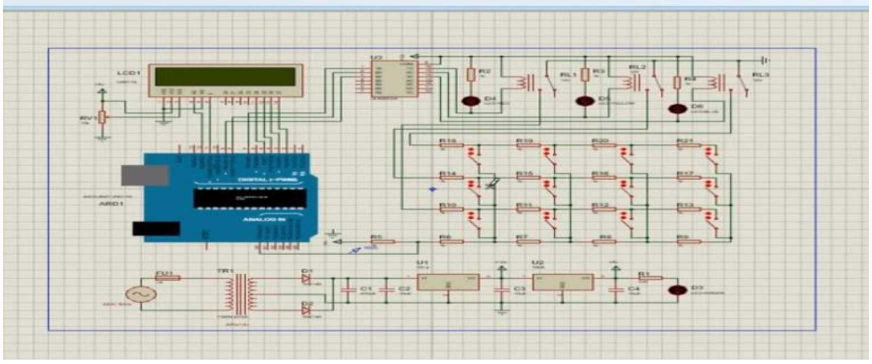

Figure 7 Simulation on No-Fault in the cable

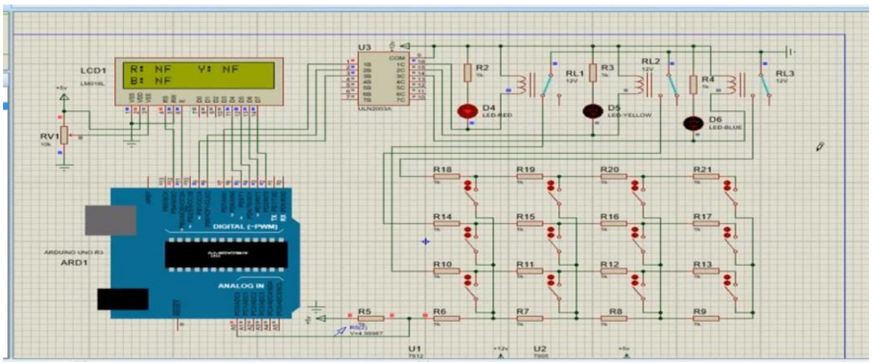

Figure 8 Simulation of fault at 2 km of Y cable

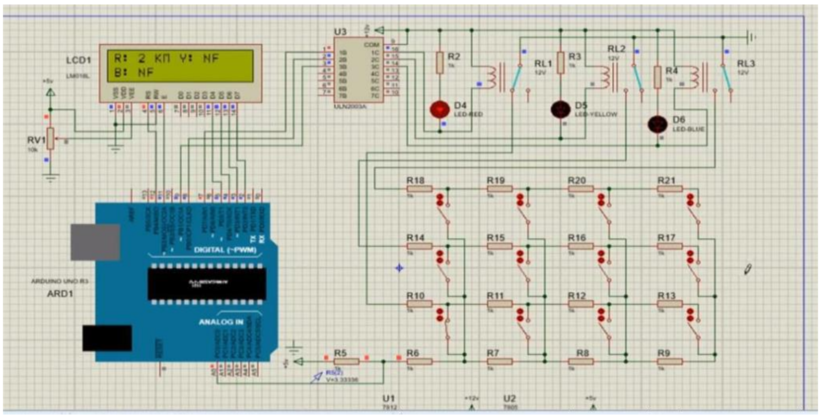

Figure 9 Simulation of fault at 2 km of R cable

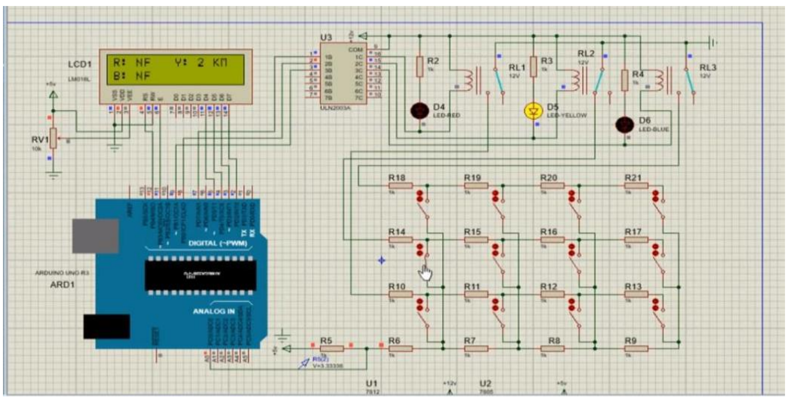

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Figure 10 Simulation of fault at 2 km of R, 4 km of Y and 6 km of G cable

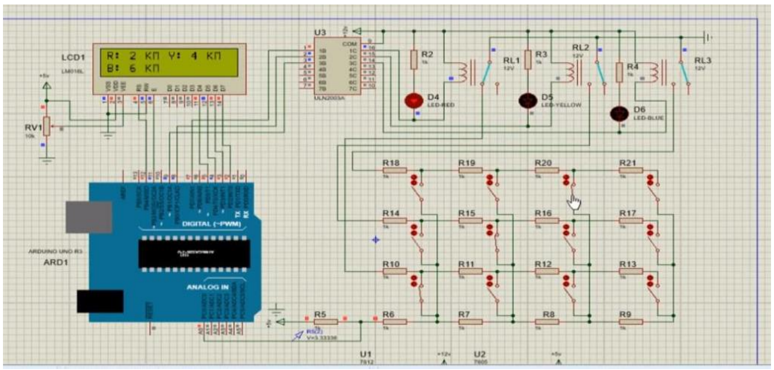

Figure 11 Hardware showing simulation of fault at 3 km of Y and 1 km of G cable

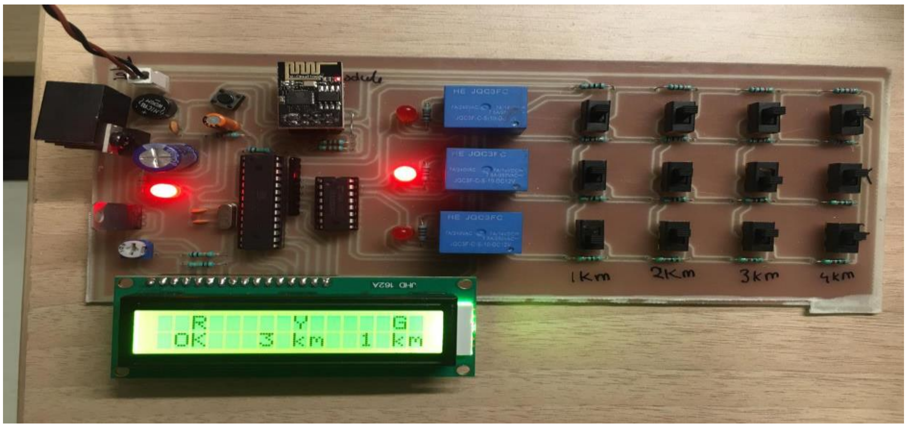

Figure 12 Hardware on simulation of no fault in the cable

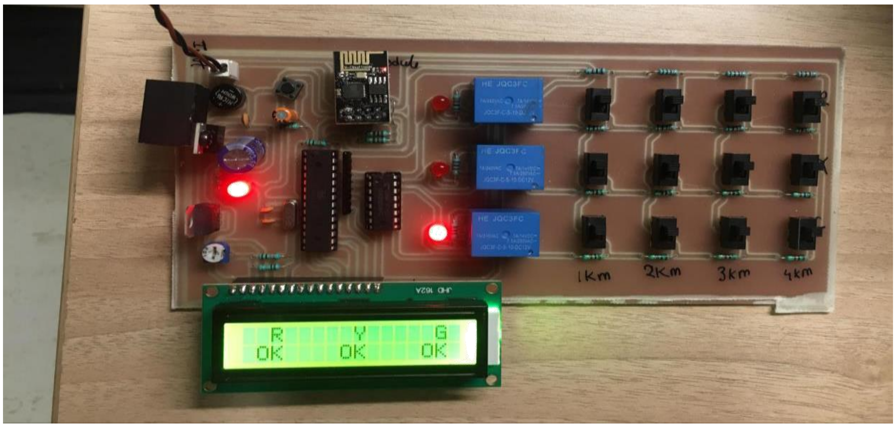

Table 1 Simulation Results

S.No.	Switch Closed	Voltage across series resistor (V)	Distance at which fault occurred (km)
1	SW11	3.33	1
2	SW10	4.00	2
3	SW14	4.29	3

4	SW24	4.44	4

Table 2 Pin Configuration of LCD display

Serial Number (Pin No)	Name
1	Vss (GND Supply)
2	Vcc (+5V)
3	Vee (Contrast Adjust)
4	RS
5	R/W
6	E
7	DB0
8	DB1
9	DB2
10	DB3
11	DB4
12	DB5
13	DB6
14	DB7
15	LED(+)
16	LED(-)